ADAPTIVE AUTOMATION AND DECISION AIDING IN THE MILITARY FAST JET DOMAIN

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ABSTRACT

The Tasking Interface Manager (TIM) seeks to demonstrate real-time adaptive automation and real-time task, interface and timeline management to support pilot operations in the Cognitive Cockpit . The intended TIM application is to enable the pilot to concentrate his/her cognitive capabilities on the tactical aspects of the mission and off-load the routine activities to automation. Ideally, this would allow the pilot to remain in a feed-forward activity (supervisory control), whilst most, if not all feedback requirements are met by decision aiding and automation. The TIM utilises output from the Situation Assessment Support System and the Cognition Monitor to adaptively present information and adaptively automate tasks according to the situational context and the pilot's internal state. The main features of a tasking interface are a shared mental model, the ability to track goals, plans and tasks, and the ability to communicate intent about the mission plan. The paper will describe the concept of operation and the technical development of the TIM.

Keywords. Cognitive Cockpit; Tasking Interface; Adaptive Automation; Shared Task Model; Intent.

INTRODUCTION

The complexity of the military aviation task domains is such that without considerable computerised assistance aircrew would not be able to cope with the very large number of potentially relevant features and a vast number of possible responses. Perceiving and interpreting all of the relevant features and choosing an appropriate response within the tight temporal constraints of the domain will challenge any intelligent agent – whether human or machine (Banbury *et al*, 1999). One method of reducing the task and cognitive load on aircrew is the provision of intelligent decision aids coupled with adaptive automation that is capable of assisting aircrew decision-making and selectively off-loading tasks. This paper describes the current state of development of a Tasking Interface component of the Cognitive Cockpit (COGPIT) programme, that allows aircrew to retain executive control of aircraft and mission parameters, whilst benefiting from such computerised assistance.

BACKGROUND

The military aviation domain is characterised by being uncertain and by having shifting goals, dynamic evolution, time stress, action feedback loops, high stakes and multiple players. While operators may wish to remain in charge, and it is critical that they do so, today's complex systems no longer permit them to be fully in charge of all system operations at all times; at least not in the same way as in earlier cockpits and workstations (Miller *et al.*, 2000). Cockpit automation has been, and will continue to grow more intelligent and more sensitive to context and mission objectives. But no one seriously believes that cockpit automation and decision aids can or should replace pilot control. Instead, they must free up pilot resources to concentrate on the most important tasks and must create in the pilot a situation awareness that allows him to make decisions correctly and very quickly.

This emerging situation begs questions about the appropriate roles for pilot and smart automation in future military aircraft. Functional integration is an important characteristic of advanced Intelligent Aiding systems, in that the required behaviour can be shared across many functional components, including the user (Geddes, 1997). That is, several functional components can collectively perform many of the same behaviours as the pilot—because they are aware of each other, capable of sharing information, aware of overall mission goals and capable of integrating their behaviours in the same way the pilot would. Functional integration of cockpit duties provides for a more robust and flexible integrated system when compared to systems based upon more strict function allocation to individual and unique components.

As the integrated automation systems in an adaptive cockpit become more aware and capable of augmenting or even replacing pilot activities in some cases, new forms of interaction between human and automation become both possible and necessary. Our goal is the creation of an adaptive or “tasking” interface that allows aircrew to pose a task for automation in the same way that they would task another skilled crewmember. It affords aircrew the ability to retain executive control of tasks whilst delegating their execution to the automation. A tasking interface will necessitate the development of a cockpit control/display interface that allows the level of automation to be changed in accordance with mission situation, pilot requirements and/or pilot capabilities. It is necessary that both the pilot and the system operate from a shared task model, affording the communication of tasking instructions in the form of desired goals, tasks, partial plans or constraints that accord with the task structures defined in the shared task model. Our efforts to construct a tasking interface, are being conducted within the context of DERA’s COGPIT program

Adaptive Interface Management

The COGPIT Technical Demonstrator will consist of four main initiatives to showcase the role of adaptive automation and intelligent decision aiding in a future manned or unmanned fast military aircraft:

- A Cognition Monitor (COGMON) that monitors the pilot’s physiology and behaviour to provide an estimation of pilot state.
- A Situation Assessment Support System (SASS) that recommends actions based on the status of the aircraft and the outside environment.
- A Tasking Interface Manager (TIM) that tracks goals and plans and manages the pilot/vehicle interface and system automation.
- A cockpit that interprets and initiates display and automation modifications upon request.

The central feature of the COGPIT is to afford the pilot the capability to concentrate his/her skills towards the relevant critical mission event, at the appropriate time and to the appropriate level. This does not necessarily imply the exclusion of all other data from the pilot, rather mission critical information will be of primary focus and other temporally non-critical, but mission important data will be presented at a lower level of salience. In order to achieve this, the COGPIT will monitor three aspects of the situation: *the environment*, both internal and external to the aircraft, *the pilot,* to take account of his/her physiological and cognitive state and *the mission plan* to indicate current and future pilot actions.

The work will exploit the lessons learnt from the U.S. Army's Rotorcraft Pilot's Associate program (RPA) programme (Miller *et al*., 1999) through consultancy with the US developer of the tasking approach. The aim will be to produce a solution tailored to the requirements of the COGPIT project, and that is compatible with the outputs of the SASS and COGMON work. The Tasking Interface Manager (TIM) will utilise the monitoring and analysis of the mission tasks provided by the SASS combined with the pilot state monitoring of the COGMON to afford adaptive automation, adaptive information presentation and task and timeline management in accordance with the requirements of the mission plan.

Functional Requirements. The functional requirements for the Tasking Interface Manager (TIM) were developed by in conjunction with Honeywell Technology Centre. The overall architecture of an adaptive cockpit we are working with involves twelve functions, with a natural flow of information and control across the functions as loosely illustrated by Figure 1.

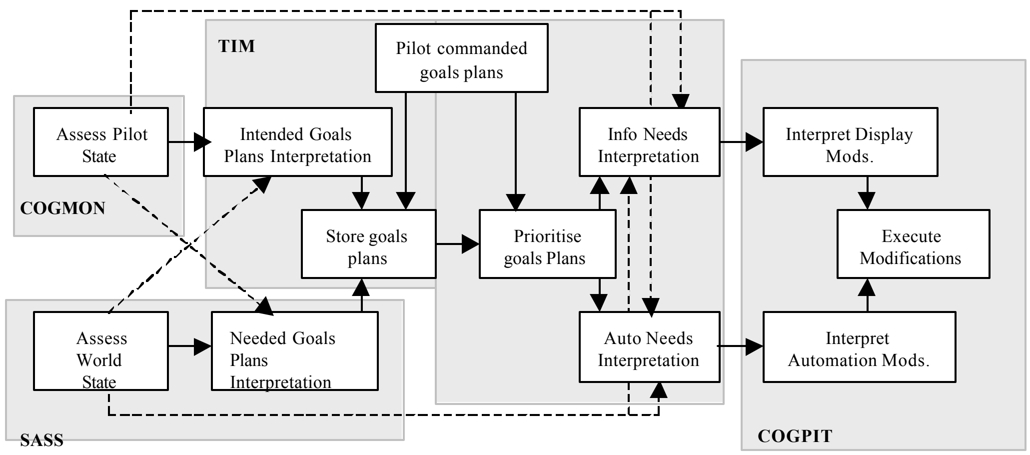

Figure 1. Flow of information across functions (⟶ primary ------▶ secondary).

Implementing TIM

Shared Task Model. In order to develop a tasking interface, it is essential that user's goals and plans be encoded, tracked and that the model of current and planned tasks be dynamically modified to keep pace with unfolding events. The use of a "task model" format shared by both the operator and the knowledge based planning system affords a high level of co-ordination between the human and the supporting system (Miller *et al*., 2000). In order to support a tasking interface a task model must be organised via functional decomposition, wherein there are alternative methods to achieve each task or goal. These tasks must be representative of the way pilots think of their domain and use operator based labelling conventions (Miller *et al*., 2000). The task model used for the COGPIT uses three task categories: tasks that never change regardless of the mission they are used for (*task generic)*, tasks which change from mission to mission but are constant within the mission *(mission specific)*, and tasks which change within the mission *(task specific).* In order for the tasking interface to determine information and automation needs, the state of the mission plan needs to be known, which involves tracking the tasks that are occurring,

TIM's Task Tracking Capabilities. There are two critical requirements of any task tracking system; it must be explicit (that is, visible to the pilot) and interactive (that is, the pilot must be able to directly input or over-ride tasks). However, in the fast jet domain you won't get acceptable tracking behaviour by relying on either task tracking or explicit task input alone. Rather there is a need to marry the two together so the system is capable of taking explicit pilot input, and even of asking for it at times, but that it doesn't have to have every little thing told to it. The functional requirement for the TIM identifies the need for a full goal plan tracking (GPT) capability, which would allow the system to track any task undertaken by the pilot. However, due to resource limitations this capability will be limited to a mission plan tracking (MPT) system in the initial TIM implementation, which will be able to track only those tasks that are instantiated in the mission plan. This will give TIM the ability to know where in the mission plan a pilot is, but not to know what s/he is doing if s/he is 'off' the originally planned mission. The MPT system will use initiation and completion algorithms to determine which tasks are active. It is acknowledged that the MPT is limited in function compared to a GPT, in that it can provide support for only those tasks that are included in the mission plan. It is intended to upgrade the MPT to full GPT status as and when resources allow.

Communication about Intent. One of the goals of TIM is to allow the pilot to interact with advanced automation *flexibly* at a variety of levels. This allows the pilot to smoothly vary the 'amount' of automation used depending on such variables as time available, workload, criticality of the decision, degree of trust, etc.—variables known to influence human willingness and accuracy in automation use (Riley, 1996). It further allows the human to flexibly act within the limitations imposed by the capabilities and constraints of the equipment and the world—a strategy shown to produce superior aviation plans and superior human understanding of plan considerations (Layton, *et al,* 1994).

There are three primary challenges involved in the construction of a tasking interface:

- A shared vocabulary must be developed, through which the operator can flexibly pose tasks to the automation and the automation can report how it intends to perform those tasks.
- Sufficient knowledge must be built into the interface to enable making intelligent choices within the tasking constraints imposed by the user. This is the role of the information and automation needs interpreters illustrated in Figure 1.
- One or more interfaces must be developed which will permit inspection and manipulation of the tasking vocabulary to pose tasks and review task elaborations in a rapid and easy fashion.

The goal is to allow the human operator to communicate tasking instructions in the form of desired goals, tasks, partial plans or constraints in accordance with the task structures defined in the shared task model. These are, in fact, the methods used to communicate commander's intent in current training approaches for U.S. battalion level commanders (Shattuck, 1995). One of the authors (Miller, et. al., 2000) has developed prototype tasking interfaces based on a "playbook" metaphor wherein the set of available plans can be described and visualised in a comparatively limited vocabulary of previously defined 'plays' that can then be adapted rapidly to the current context. It is intended to use a variation of the playbook metaphor for the TIM.

Adaptive Automation. Analysis of the operator requirement for pilot authorising and control of levels of automation, with the envisioned TIM support, has led to the development of the COGPIT Plot Authorisation and Control of Tasks (PACT) system. The PACT system uses military terminology (Under Command, At Call, Advisory, In Support, Direct Support, Automatic) to distinguish realistic operational relationships for five aiding levels, with progressive pilot authority and computer autonomy supporting situation assessment, decision making and action (Table 1). These are a reduced, practical set of levels, with clear engineering and interface consequences, derived from the ten levels of automation for human-computer decision-making proposed by Sheridan and VerPlanck (1978). The PACT terminology and selection of levels are based on operational considerations that are consistent with theory, to afford usability and compatibility with military user cognitive schemas and models. It is envisaged that mission functions and tasks, at different levels of abstraction, will be allocated to these levels. The operator could control this allocation in a number of ways:

- pre-set operator preferred defaults,
- operator selection during pre-flight planning,

- changed by the operator during in-flight re-planning,
- automatically changed according to operator agreed, context-sensitive adaptive rules.

Levels	Operational Relationship	Computer Autonomy	Pilot Authority	Adaptation	Information on performance
5	**Automatic**	Full	Interrupt	Computer monitored by pilot	On/off Failure warnings Performance only if required.
4	**Direct Support**	Action unless revoked	Revoking action	Computer backed up by pilot	Feedback on action. Alerts and warnings on failure of action.
3	**In Support**	Advice, and if authorised, action	Acceptance of advice and authorising action	Pilot backed up by the computer	Feed-forward advice and feedback on action. Alerts and warnings on failure of authorised action.
2	**Advisory**	Advice	Acceptance of advice	Pilot assisted by computer	Feed-forward advice
1	**At Call**	Advice only if requested.	Full	Pilot, assisted by computer only when requested.	Feedforward advice, only on request
0	**Under Command**	None	Full	Pilot	None, performance is transparent.

Table 2. PACT System for Pilot Authorisation of Control of Tasks.

Usage Scenario

The intended TIM application is to enable the pilot to concentrate his/her cognitive capabilities on the tactical aspects of the mission (knowledge-based) and off-load the routine (rule-based and skill-based) activities to automation. In effect this will allow the pilot to remain in a feed-forward loop whilst, most, if not all feedback requirements are met through decision aiding and automation.

- The SASS provides rule-based decision-aiding information, according to the situational context. For example progressively providing avoid, evade and defeat action requirements against ground and air threats as the scenario develops.
- The COGMON provides pilot state information (cognitive capability) according to the pilot's physiological condition. For example provide the TIM with the information that the pilot is high on visual and cognitive workload coupled with a high alertness and high arousal but low activity.
- The TIM affords the ability to adaptively provide information according to the situational context and pilot state and to either selectively (pilot controlled) or adaptively (TIM controlled) offload tasks to automation in accordance with the mission plan.
    - The pilot could selectively increase the automation level on aspects of the Defensive Aid System (DAS) and aircraft defensive manoeuvres to afford concentration on the ramifications of the threat avoidance to mission completion
    - TIM could adaptively increase these same DAS and manoeuvre aspects to accord with the situational context if the pilot state was such that either cognitive or physical function was partially impaired.

CONCLUSION

Useful assistance in the management of cockpit interfaces, tasks and automation can be provided by a tasking interface system based on a shared task model. The development of an effective TIM, with which pilots can interact easily, will be critical for the successful integration and acceptance of the outputs of the COGMON and SASS sub-systems. The technical specification of a tasking interface for this type of system, is a major task, particularly as the functional components require iterative development, precluding early definition of inputs and outputs. The use of a tasking interface allows the pilot to maintain executive control of the aircraft and mission whilst enabling almost full autonomy for an aiding agent. We believe that the TIM will act like an intelligent subordinate, that can be directed when necessary, but will be given autonomy when it shows it has the capability.

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